PHYSICS WITHOUT *PHYSIS*: ON FORM AND TELEOLOGY IN MODERN SCIENCE

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"[T]he metaphysical framework that rendered matter intelligible disintegrated and with it the notion of nature itself."

Physics is often regarded as the most fundamental natural science. In its modern guise, it is concerned with matter, energy, and their interrelation over time and through space. Experimental physics deals with observations and measurements of the smallest and greatest dimensions of the universe. This blends with theoretical physics, which develops abstract mathematical models to explain experimental findings, proffering speculative possibilities concerning the workings of physical systems. As experimental technologies develop, so the overlap between experimental and theoretical physics increases; previously abstract and speculative models become empirically testable. While the possibility of reducing the other natural sciences to physics without remainder is now credible only among the most hardened of materialists, modern physics remains the quintessential science of nature (*physis*). It apparently delivers fundamental and comprehensive

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knowledge of the cosmos, from the subatomic quantum realm to the furthest reaches of space and time.

The story of the rise of modern physics is long and complex: from the demise of Aristotelian natural philosophy in the late Middle Ages and its successive replacement by Galilean, Cartesian, and Newtonian physics, to the revolution inaugurated in the twentieth century by special and general relativity, quantum mechanics and quantum field theory. One of the most striking aspects of this story is that, as physics apparently confined itself ever more exclusively to the study of an abstract matter and its behavior, thus yielding materialist ontologies, the nature of matter has become increasingly mysterious. It is almost as if matter has dissolved under the gaze of modern science, which at the same time insists that matter is all that exists. As a consequence, it appears that physics' grasp of the *physis* it purports to study—any sense of nature's integrity, wholeness, and purpose, which we grasp intuitively—has become ever more tenuous.

The story of the increasingly mysterious nature of matter uncovered by modern physics is at once a story of ever greater abstraction, including abstraction from any metaphysical framework within which matter would be intelligible. For Aristotle, matter (*hylē*) was conceived within a delicately woven physics and metaphysics. Material natures were understood in relation to form within the wider category of substance and the fundamental metaphysical distinction between act and potency. According to Aristotle, matter was a relative term that cannot be studied except under the aspect of the forms received by matter and within the context of the distinction between act and potency.[1] For Newton, by contrast, matter or "body" was a quantity (mass) and a basic category derived from experience and subject to force. Matter was fundamental to the new mechanics.

> The extension, hardness, impenetrability, mobility, and force of inertia of the whole arise from the extension, hardness, impenetrability, mobility and force of inertia of each of the parts; and thus we conclude that every one of the least parts of all bodies is extended, hard, impenetrable,

1. Aristotle, *Physics* II.2, 194b9.

> movable, and endowed with a force of inertia. And this is the foundation of all natural philosophy.[2]

Nevertheless, despite the stunning predictive and explanatory success of the new natural philosophy, the problem of gravity and action at a distance presented significant challenges to Newton's materialist mechanics. The transmission of gravitational force suggested the existence of an ether between gross bodies through which that mechanical force could be transmitted, yet its nature and status were mysterious and highly contested.[3] Arguably, this remains true in contemporary physics with respect to the nature and status of fields.

It was not until the early decades of the nineteenth century that more significant and decisive blows were dealt to classical Newtonian mechanics as an all-encompassing account of the physical world. In 1864, building on the earlier work of Michael Faraday and André-Marie Ampère, James Clerk Maxwell presented to the Royal Society of London his treatise *A Dynamical Theory of the Electromagnetic Field*, in which he united the fields of electricity and magnetism. He postulated that electricity, magnetism, and light are waves that move through space, much as a wave moves across the sea. Albert Einstein was later to claim that "the greatest change in the axiomatic basis of physics, and correspondingly in our conception of the structure of reality, since the foundation of theoretical physics through Newton, came through the researches of Faraday and Maxwell on electromagnetic phenomena."[4] This moved physics away from the study of matter per se toward the study of fields.[5] At the same time,

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2. Isaac Newton, *The Principia: Mathematical Principles of Natural Philosophy* (*Philosophiae Naturalis Principia Mathematica* [1726]), trans. I. B. Cohen and A. Whitman, 3rd ed. (Berkeley: University of California Press, 1999), bk. 3, 795–96.

3. For a brief account of Newton's views of the ether, see Simon Oliver, *Philosophy, God and Motion* (London: Routledge, 2005), 175–77.

4. Albert Einstein, "Maxwell's Influence on the Development of the Conception of Physical Reality," in James C. Maxwell, *A Dynamical Theory of the Electromagnetic Field*, ed. Thomas F. Torrance (Edinburgh: Scottish Academic Press, 1982), 29.

5. For an account of the development of field theories in physics, see Ernan McMullin, "The Origins of the Field Concept in Physics," *Physics in Perspective* 4 (2002): 13–39.

a new science of "thermodynamics," claiming to unify physics and chemistry, was proposed in the 1850s and 1860s by William Thompson and Peter Guthrie Tait. Their *Treatise on Natural Philosophy* of 1867 presented a science of the dynamics of energy ("energetics") rather than the Newtonian dynamics of force; this drew physics further away from any simple notion of matter toward energy as its primary focus of inquiry. Energy, rather than mere matter, was preserved through change. How energy related to matter was an open question, which received its first cogent answer in Einstein's simple and emblematic equation $E=mc^2$.[6] This was the basis of the special theory of relativity, which, referring to uniform motion, postulated that rest mass can be transformed into kinetic or radiant energy, and vice versa. Mass was now understood as just one form of energy.

Einstein's general theory of relativity, developed between 1907 and 1915 as an extension of special relativity, accounted for gravity in terms of a warping of spacetime.[7] Whereas Newton's law of universal gravitation assumed that mass was the sole source of gravity, Einstein now proposed that, in addition to rest mass, other forms of energy were sources of gravitational agency. Even a body of zero mass—a photon, for example—exerts a gravitational force due to its kinetic energy. According to general relativity, mass, energy (including potential energy), and momentum all serve as sources of gravity expressed mathematically as the stress-energy (or energy-momentum) tensor. This

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6. Einstein's famous paper of 1905, "Ist die Trägheit eines Körpers von seinem Energieinhalt abhängig?" first published in *Annalen der Physik*, demonstrates the equivalence of mass and energy. It is reproduced in translation as "Does the Inertia of a Body Depend upon Its Energy Content?" in A. Einstein, H. A. Lorentz, H. Minkowski, and H. Weyl, *The Principle of Relativity: A Collection of Original Memoirs on the Special and General Theory of Relativity*, trans. W. Perrett and G. B. Jeffery (New York: Dover, 1952), 67–71. The particular reasoning of that paper has since been subject to criticism, and Einstein's indebtedness to earlier work in thermodynamics is now well understood. Nevertheless, the power, simplicity, and cultural significance of Einstein's work is beyond doubt. See Max Jenner, *Concepts of Mass in Contemporary Physics and Philosophy* (Princeton: Princeton University Press, 2000), chap. 5.

7. Einstein's development of general relativity culminated in the publication of his "The Field Equations of Gravitation" in November 1915. His paper "The Foundation of the Generalised Theory of Relativity" was published the following year and is available in Einstein et al., *The Principle of Relativity*, 109–64.

represented a remarkable transformation in physics and its primary object of inquiry, which could now be twofold: either the new single category of mass-energy, or simply rest mass (devoid of motion) and a separate category of energy. As Ernan McMullin comments,

> This is a startling demotion of matter as the sole carrier of the "reality" label. Something without mass is, by the Newtonian definition at least, something without any quantity of matter. Massless radiation would not, then, qualify as matter. The Einstein equivalence equation [of energy and mass] has, in effect, begun the "dematerialization" of physical reality. The only way in which the world can still be described as the "material" world, or the term materialism can preserve its original significance, is to redefine "matter." But how? Materialism, if one wants to retain the term, seems to have unexpectedly become a much more open doctrine.[8]

It is certainly the case that the nature of materiality has been contested for centuries. The ambiguous nature of light, for example, was already apparent in the seventeenth century in the debate between Newton and Huygens concerning the corpuscular and wave theories. By the early twentieth century, it was clear that light had to be conceived as both a wave and a particle. Such ambiguity now belongs to matter in the subatomic domain. The very high level of abstraction and the ambiguous nature of phenomena treated by contemporary physics means that matter is not *simply* convertible with other forms of energy; it becomes a strangely amorphous concept in the world of subatomic quantum physics. The term "quantum" relates to the hypothesis that energy is parcelled into discrete "quanta," a view proposed by Max Planck in 1900 to account for bodies' variable emittance of electromagnetic radiation. This new

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8. Ernan McMullin, "From Matter to Materialism. . . and [Almost] Back," in *Information and the Nature of Reality: From Physics to Metaphysics*, eds. Paul Davies and Niels Henrik Gregersen (Cambridge: Cambridge University Press, 2010), 24. For a further brief summary, see Philip Clayton, "Unresolved Dilemmas: The Concept of Matter in the History of Philosophy and in Contemporary Physics," in *Information and the Nature of Reality*, 38–57; and Edward Feser, *Aristotle's Revenge: The Metaphysical Foundations of Physical and Biological Science* (Neunkirchen-Seelscheid, Germany: Editiones Scholasticae, 2019), chap. 5.

physics would present very unexpected but mathematically coherent phenomena.

One example of quantum strangeness arises from the superposition principle. Imagine a physical system that consists of just one subatomic particle, and two states of that system in which the particle is located first in region A and then in region B. Quantum physics stipulates that in a linear combination of these two states, the particle is mysteriously located in both regions. This does not mean that we cannot tell whether the particle is in region A or region B; its position really is indeterminate. It is possible to reproduce experimentally the linear combination of states in such a way that interference effects are observed that would not be present were the particle situated in *either* region A *or* region B. Therefore, the particle appears to be in both regions simultaneously. In a fashion similar to probabilistic calculations relating to heat in thermodynamics, it is possible to calculate probabilities for the particle being in different positions. There is therefore a twofold mystery in quantum theory: first, the bilocation of particles that is unimaginable in a classical Newtonian view of the cosmos, and, second, a purely probabilistic nature, at least at a quantum level. In a situation where a particle bilocates in this way, however, its position may be fixed by experimental observation. The act of measuring sends the system into a new state in which the location of the particle can be identified—the so-called "collapse of the wave function." This is commonly known as the Copenhagen interpretation of quantum theory, which claims that a quantum system remains in a state of superposition until it is observed or interacts with something beyond that system.

Such strange phenomena appear to take place only at a subatomic level. Apparently, they do not impinge at the level of macroscopic nature. The famous thought experiment known as "Schrödinger's Cat," however, demonstrates how quantum effects can, in theory, bear upon the macro physical level.[9] Schrödinger describes a cat confined to a steel chamber with a canister of hydrocyanic acid. The release of the gas will be triggered via a Geiger counter, which contains a tiny piece of ra-

9. E. Schrödinger, "Die gegenwärtige Situation in der Quantenmechanik," *Naturwissenschaften* 23 (1935): 807–12.

dioactive material, one atom of which may or may not decay within the hour. If it decays and triggers the gas, the cat will be dead; if not, the cat will be alive. According to quantum theory, however, the radioactive nucleus of the material contained in the Geiger counter, which is unobserved, is in a superposition state; that is to say, as it decays one cannot be sure whether its location will be such as to trigger the release of the gas. Just as in the case of the bilocated particle above, it is in the act of measurement that the state of the system (whether the cat is dead or alive) is determined. The radioactive nucleus is in a superposition state and transfers this to a macro level by placing the cat in a similarly indeterminate state. The act of measurement then determines the state of the cat. However, what is more curious still is that, whatever one observes in the box, a cat that is alive or dead, it is not possible to provide a compelling reason why that particular state, rather than its alternative, pertains. Nature appears to be governed, even at a macro level, by probability.

In this thought experiment, Schrödinger intended to show that there was no coherent account of why a superposition could not transfer to macro-nature. Why do we not experience the superposition of macroscopic bodies? If photons, for example, can bilocate at the quantum level, it seems reasonable to suppose that bodies composed of photons should also bilocate. As the physicist Roger Penrose states, "Why, then, do we not experience macroscopic bodies, say cricket balls, or even people, having two completely different locations at once? This is a profound question, and present-day quantum theory does not really provide us with an answer."[10] The relationship between these two worlds—the subatomic domain of quantum indeterminacy and the macroscopic domain of predictable certainty—is fundamentally unclear; our familiarity with the latter entails that the former appears strange and even paradoxical.

If contemporary physics is concerned with matter, the nature of its object of study is therefore mysterious and complex. Insofar as nature is understood in material terms, the grasp of nature by physics has become ever more tenuous. The ambigui-

10. Roger Penrose, *The Emperor's New Mind* (Oxford: Oxford University Press, 1989), 256. See also Wolfgang Smith, "From Schrödinger's Cat to Thomistic Ontology," *The Thomist* 63 (1999): 49–63.

ties of matter—both its nature and behavior—lie at the root of today's scientific inquiry. In fact, contemporary cosmology understands that less than five percent of the universe is composed of ordinary, baryonic matter. The remainder is composed of so-called dark matter, which is detected only via its gravitational effect on galaxies, and dark energy, which repels gravity.

Against the background of the understanding of matter and nature in contemporary physics, in this article I will initially return to the premodern metaphysical framework that once supported natural philosophical inquiry in order to appreciate more clearly why modern science's grasp of its own subject matter has become tenuous. This is not an arbitrary or nostalgic return to ancient thought because Aristotle's physics and metaphysics was already an answer to the perceived inadequacies of the materialist atomism of Leucippus and Democritus. It will be seen that the metaphysical categories of act and potency, form and matter, along with the primacy of final causation, render matter and nature intelligible for Aristotle and his medieval commentators. While it is the case that the transition from the Aristotelian and Neoplatonic understanding of nature to the modern scientific worldview can be narrated in terms of the rise of mechanistic materialism and the rejection of purpose or final causes, it will be argued that the demise of formal causation and the primacy of wholes over parts lay at the root of this development. This meant that the metaphysical framework that rendered matter intelligible disintegrated and with it the notion of nature itself. The advent of quantum theory in the early twentieth century heralded a turn away from mechanism toward a more organic understanding of nature, which, despite the paradoxical and seemingly counter-intuitive findings of contemporary physics and the increasingly problematic status of matter, suggests a clearer vision of nature's unity and intelligibility, which in many ways revives the Aristotelian approach to natural philosophy.

This article will therefore proceed in three stages. First, the physics and metaphysics of form and finality in Aristotle and his principal medieval interpreter, Thomas Aquinas, will be examined in order to understand the context in which material nature was understood prior to the advent of classical physics in the seventeenth century. Second, it will be argued that, in the advent of mechanistic physics in the seventeenth century, purpose in nature remained an important aspect of natural philosophical explanation, but such purpose became increasingly unintelligible because of the demise of formal causal explanation. With this demise came an increasingly abstract understanding of matter and the dissolution of the concept of nature understood as a series of wholes that constitute the subject matter of scientific enquiry. Finally, I will turn to contemporary physics and the interpretation of quantum theory, particularly David Bohm's understanding of the implicate and explicate order of nature. It will be argued that Bohm understands nature as an organic whole in a more Aristotelian fashion in such a way that every part of nature is an expression of the whole and ordered toward that whole. This represents a return to the view that natural scientific inquiry is concerned with abstracted parts of nature that are only intelligible in relation to the whole of which they are a part. Nevertheless, that whole is only finally understood metaphysically and theologically.

ARISTOTLE ON PHYSICS, METAPHYSICS, FORM, AND FINALITY

The fundamental metaphysical distinction that structures Aristotle's physics is that between actuality (*energeia*) and potentiality (*dunamis*). This distinction applies to all finite being because everything, as subject to change (*kinesis*), is *actually* something (a child, for example) and *potentially* something else (an adult).[11] This distinction is the framework for Aristotle's definition of motion, the category at the heart of his physics, which hovers between potency and act. Motion is the actualization of a potency qua potency.[12]

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11. Aristotle assumes this nuanced distinction throughout his *Physics* and *Metaphysics*. The most detailed treatment can be found in *Metaphysics* IX. See also Aristotle's *De Anima* II.5, 417a21–b2.

12. Motion is "the actualization of what potentially is, as such; for example the actual progress of qualitative modification in any modifiable thing qua modifiable; the actual growing of a thing or shrinking . . . of anything capable of expanding or contracting; the process of coming into existence or passing out of it of that which is capable of so coming and passing; the actual moving of a physical body capable of changing its place" (Aristotle, *Physics* III.1, 201a). The English translation of Aristotle's *Physics* throughout this essay are by P. H.

Paramount in Aristotle's thought is the primacy of act over potency.[13] It may be that potency precedes actuality in time; for example, the acorn, which is potentially an oak tree, comes chronologically prior to the oak tree. Actuality, however, is always prior to potentiality both in formula (*logos*) and substance, for potentiality is always a potential *for* an actuality that is ontologically prior. Act always "measures" potency, for potency is only understood in relation to act. Any motion (by which Aristotle means any kind of change) requires something in act to reduce that which is in potency to act.[14]

Aristotle understands matter within this fundamental metaphysical context of act and potency. Matter itself, which Aristotle calls "prime matter" (*prōtē hulē*) or "primary underlying thing" (*prōton hupokeimenon*),[15] is a pure potency—not anything in particular—and is therefore strictly speaking unintelligible and not even existent. In being potential in itself, matter is always already actualized as a particular "something" through its form. Its first and absolute potential is therefore for the reception of form. Form is the "what it is to be" something; it is intrinsic to

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Wicksteed and F. M. Cornford and can be found in the Loeb Classical Library edition, 2 vols. (Cambridge: Harvard University Press, 1996). On the interpretation of Aristotle's definition of motion as the actualization of a potency qua potency, see L. A. Kosman, "Aristotle's Definition of Motion," *Phronesis* 14 (1969): 40–62; and Oliver, *Philosophy, God and Motion*, chap. 2. In order to avoid a circular or tautologous definition of motion, Aristotle stipulates that motion is the actualization of a potency *as a potency*. For example, if I am currently in London, I am equally potentially in Edinburgh and potentially in Cardiff. My motion to Edinburgh (rather than Cardiff) on a train is the actualization of my potential to be in Edinburgh *as a potential*. When I arrive in Edinburgh, that potential is fully actualized. By defining motion as the actualization of a potency *as a potency*, Aristotle captures motion's intermediate status between potency and act while not resorting to a tautology such as "motion is passage from potency to act."

13. Aristotle, *Metaphysics* IX.8, 1049b4–15. See also Thomas Aquinas, *Commentary on Aristotle's* Metaphysics, trans. John P. Rowan (Notre Dame: Dumb Ox Books, 1995), 611 (IX.7, 1846). All references to Aquinas's *Commentary* are from this edition.

14. Strong echoes of the distinction between act and potency remain in the notion of potential energy in modern physics. See Thomas McLaughlin, "Act, Potency, and Energy," *The Thomist* 75 (2011): 207–43.

15. See, for example, *Physics* I.9, 192a31; *Physics* II.1, 193a10; *Metaphysics* V.4, 1014b32; V.6, 1017a5–6. *Metaphysics* VII.3, 1029a20–30, although not featuring the phrase "prime matter," is particularly instructive.

something's nature and defines that nature.[16] Indeed, the forms of things are closely allied to nature, which is "the distinctive form or quality of such things as have within themselves a principle of motion, such form or characteristic property not being separable from the things themselves, save conceptually."[17] The intrinsic principle of motion in nature allows Aristotle to distinguish nature from art and to claim that art always imitates nature; art has an extrinsic principle of motion in the maker or operator. Furthermore, this allows Aristotle to identify where the attention of the physicist must lie.

> How far then, is the physicist [*phusikon*] concerned with the form and identifying essence of things and how far with their material? With the form primarily and essentially, as the physician is with health; with the material up to a certain point, as the physician is with sinew and the smith with bronze. For his main concern is with the goal, which is formal; but he deals only with such forms as are conceptually, but not factually, detachable from the material in which they occur.[18]

This passage gestures toward the fundamental link between the formal and final cause in Aristotle's physics and metaphysics: form is the final cause.[19] Every dynamic substantial form is defined fundamentally by the goal toward which it strives. The mode of final causation, the "cause for the sake of which," is fundamental for Aristotle because without a goal or purpose there would be no intelligible agency in nature.[20] Among the

16. *Physics* II.1, 193a28–35: "This then is one way of regarding 'nature'—as the ultimately underlying material of all things that have in themselves the principle of movement and change. But from another point of view we may think of the nature of a thing as residing rather in its form, that is to say the 'kind' of thing it is by definition."

17. *Physics* II.1, 193b.3–6.

18. Ibid., II.2, 194b.10–14.

19. Ibid., II.8, 199a33.

20. Ibid., II.3, 194b.30. For Aquinas on agency and final causation, see *Summa theologiae* I-II, q. 1, a. 2 co (hereafter cited as *ST*): "Every agent, of necessity, acts for an end. For if, in a number of causes ordained to one another, the first be removed, the others must, of necessity, be removed also. Now the first of all causes is the final cause."

four modes into which cause falls (efficient, material, formal, and final), the final cause is the most fundamental in natural philosophical explanation because it answers the "why" question and gives an account of natural agency. All other modes of causation are derivable from the final cause. As Aquinas put it, "Whence it is said that the end is the cause of causes, because it is the cause of the causality in all the causes."[21]

In his discussion of final causation, Aristotle makes an important distinction between the goal as the aim of an action ("that of which") and the goal as the beneficiary ("that for which").[22] For example, the aim of the art of medicine is health ("that of which"), whereas the beneficiary of the art of medicine is the patient ("that for which"). A physician has health as the goal of her art; at the same time, there is a beneficiary in the form of the patient whose health is restored. This distinction is important for Aristotle in a number of respects. For example, it can be seen that the first unmoved mover is the end of motion not in the sense of being a beneficiary (because, in being fully actual, the first unmoved mover cannot benefit from anything), but in the sense of being the aim or focus of desire. I will return shortly to Aristotle's distinction between the final cause as aim and the final cause as beneficiary.

The priority of act over potency helps to answer a very common charge made against final causation, namely that it involves mysterious backwards causation. This criticism reveals the extent to which efficient causation dominates our contemporary understanding. Take the example of an acorn growing toward the goal of being an oak tree. That oak tree, yet to be realized from the acorn, causes the acorn to grow. On one interpretation, there is some kind of causal "pull" exerted by these goals or aims, in this case the oak tree. But how could a tree that does not yet exist cause this acorn to grow in the here and now? Yet this is to treat the final cause as if it were some kind of efficient

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21. Thomas Aquinas, *De principiis naturae*, ed. and trans. Joseph Bobik, *Aquinas on Matter and Form and the Elements: A Translation and Interpretation of the* De Principiis Naturae *and the* De Mixtione Elementorum *of St. Thomas Aquinas* (Notre Dame: University of Notre Dame Press, 1998), 60 (chap. 4, §22).

22. *De Anima* II.4, 415b1–7. See also *Physics* II.2, 194a35–b3; *Metaphysics* XII.7, 1072b2–6.

cause pulling the acorn toward becoming an oak. The key is to recognize that final causes are prior in nature and definition, but are in some senses last in the order of generation or time. In the case of the acorn, the final cause (being an oak tree) must come first in the order of explanation and intelligibility, like actuality itself. In the temporal order or the order of generation, the final cause, like actuality that results from the realization of a potency, comes last because it is the outcome of the development of the acorn into the oak. This is even clearer in the case of human intentional action: I decide that I want to get fit, so I go running, the result of which is my fitness. In the order of explanation or intelligibility with respect to the final cause, I must start with the identification of the goal of getting fit, which is the final cause of me running; running is, in turn, the efficient cause of me getting fit. The order of explanation begins with the final cause and ends with the result. In the order of generation or time, the goal comes last. Aristotle never claimed that the final cause mysteriously acts as an efficient cause by exerting some kind of "pull" toward the goal. Neither did he regard the formal cause to be a mysterious "pushing" efficient cause within the creature. The blending of formal, final, efficient, and material causes, with the final cause as primary and fundamental, helps to create explanatory adequacy. This is why Aristotle and Aquinas regard final causes as so fundamental: they come first in the order of explanation and intelligibility, for the *telos* "is the cause of the causality in all the causes."

According to both Aristotle and Aquinas, the formal and final modes of causation account for the fundamental structure of nature as the object of natural philosophical inquiry. In *Metaphysics* 5, Aristotle discusses the various modes of causation and Aquinas, in his commentary, delineates the different levels of formal unity in material substances.[23] First, there is form, which is simply the shape given to material, as for example silver that is fashioned into a goblet. Second, there is the form of something, which arises merely from the proximate arrangement of parts, as for example the soldiers in an army or the houses in a city. Third, there is the form, which comes from the arrangement of

23. *Metaphysics* V.2, 1013b16–1014a25; Aquinas, *Commentary on Aristotle's* Metaphysics, 287 (V.3, 779).

parts and their extrinsic bonding. An example would be a house whereby the composition of bricks bonded by mortar has the role of a form. Finally, there is the more fundamental unity that belongs to a compound (*mixtione*) whereby the component parts themselves are "re-formed" into a new unity with a singular dynamic substantial form that possesses an intrinsic principle of motion toward an end. These different levels of formal causation allow Aristotle to identify where nature, as opposed to artifice, is to be found: it lies within that fundamental substantial unity that possesses a singular form—an irreducible whole—that features an intrinsic principle of motion.[24] The crucial point in Aristotle's metaphysical scheme, however, concerns priority in the order of explanation and the order of the real. The unity of form may come sequentially last in time, but it is first in "formula and substance," for it realizes the material as a substantial *and therefore intelligible* unity. Both Aristotle and Aquinas locate nature in the intelligible unity of form instantiated in matter. Meanwhile, the material elements in any dynamic substantial unity are intrinsically related to each other in the sense that what affects one affects the others. This is the subject matter of the natural philosophy we call physics.

The form, however, is at once the final cause. Aristotle's conception of nature studied by the physicist is fundamentally teleological. The final good of every natural substance is its full actuality and perfection, and therefore its good.[25] Its potency is intelligible in relation to the actuality of its goal. In *Metaphysics* 12, Aristotle discusses the nature of the good and whether that good is something separated, or whether it is immanent within the order of things: "We must also consider in which sense the nature of the universe contains the good or the supreme good; whether as something separate and independent, or as the orderly arrangement of its parts."[26] He uses the example of an army. Does its good lie in the ordered relation of the soldiers, or in the general who stands above them, or in both? Aristotle concludes that the good lies in both, but more in the general because "he is not

24. *Metaphysics* V.4, 1015a14–19.

25. Ibid., V.2, 1013b25–29.

26. Ibid., XII.10, 1075a12–15.

due to the order, but the order is due to him."[27] In any order, Aristotle concludes that all things are jointly ordered with respect to one thing in which they all share or participate. For some interpreters, this implies that the good is immanent in the individual members of any order simply by virtue of what they are. However, Aristotle wants to point out that all individuals work toward a good that transcends their individuality and constitutes a good for the whole. This is certainly the case in Aristotle's politics, in which an individual realizes his good by realizing the good of the city, which exists for the good life. More importantly, it should be remembered that Aristotle does not think in terms of separated and discrete systems in either politics or nature. So, we might say that any given order composed of individuals (the metaphor of an army regiment) will itself be part of a wider order (the metaphor of a nation's army) and work for its own good, which is constituted also by the good of the whole. For any given order, there is yet another good that transcends that particular order. Aristotle can therefore state in the *De Anima* that "every creature strives for this [the divine], and for the sake of this performs all its natural functions."[28]

Aristotle's teleological physics and metaphysics, centered fundamentally on formal and final causes, is framed theologically by reference to an ultimate or last end. A purely naturalized teleology—a pattern of finite ends, every one of which is intermediate and pertains to a further end—leads to an infinite regress that would be explanatorily incomplete with respect to the agency and order in nature that are the very basis of there being natural scientific inquiry. Aristotle's distinction between the final cause as the aim of an action (for example, health as the goal of medicine) and the final cause as the beneficiary (the patient whose health is restored) is important in this regard. Precisely in striving for the final cause as the aim of an action, every creature at the same time is the beneficiary as it fulfils its nature. A separate (*kechōrismenon*) and transcendent final cause is required for explanatory completeness—that which is the end of all ends, as

27. Ibid., XII.10, 1075a17–18.

28. *De Anima* II.4, 415b1–2.

having no end beyond itself because of its eternal aseity.[29] Thus the primacy of the mover that is itself unmoved as the ultimate framework for the intelligibility of matter, form, and the modes of causation studied by physics, is an aspect of the explanatory principle that act precedes and measures potency.

Aristotle therefore understands the final cause to be both transcendent in the ultimate good and final end of all things, and intrinsic in the orientation of natures to a participation in that final end through their own perfection. The Aristotelian account of teleology therefore avoids a critical dualism that besets many modern discussions, namely that between intrinsic and extrinsic teleology. As we will see, the understanding of final causation in early modern physics tended to assume that matter is passive and inert in such a way that any orientation to a final end is extrinsic to a material entity after the manner of an artifact. This tended to reverse the traditional principle that art imitates nature; for the physico-theologians of the seventeenth and eighteenth centuries, nature was understood to be akin to an artifact such as a machine. Meanwhile, attempts have been made to defend a purely naturalized teleology that avoids any need for a transcendent principle of goodness or being.[30]

I now turn to the advent of modern physics and its more exclusive focus on efficient causation to the exclusion of form and finality. The absence of a thoroughgoing and intelligible metaphysics of the natural meant that physics was unable to maintain a grasp of the object of its study.

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29. Aquinas makes this particularly clear with respect to human intentional agency and man's last end. Nevertheless, such desire for the supernatural is part of nature's desire for the good in itself, namely God. See Aquinas, *ST* I-II, q. 1, a. 6 co: "Man must, of necessity, desire all, whatsoever he desires, for the last end. This is evident for two reasons. First, because whatever man desires, he desires it under the aspect of good. And if he desire it, not as his perfect good, which is the last end, he must, of necessity, desire it as tending to the perfect good, because the beginning of anything is always ordained to its completion; as is clearly the case in effects both of nature and of art. Wherefore every beginning of perfection is ordained to complete perfection which is achieved through the last end."

30. For a nonmaterialist but naturalist account of teleology, see Thomas Nagel, *Mind in Cosmos: Why the Materialist Neo-Darwinian Conception of Nature Is Almost Certainly False* (Oxford: Oxford University Press, 2012).

FROM FORM AND FINALITY TO MECHANISM AND MATERIALISM

It is very common to narrate the rise of modern natural philosophy from the sixteenth century in terms of the demise of the ancient and medieval teleological cosmos and its replacement by a purposeless mechanistic cosmos. Final causes were apparently regarded as unnecessary for the proper explanation of natural phenomena. Francis Bacon, the Elizabethan father of the scientific method, claimed that final causes might be useful in the explanation of goal-orientated human intentional actions, but are otherwise barren.[31] Wider nature, however, is to be explained not by final causes but by efficient causes, now understood as those events that immediately precede an effect in time and transmit their causal power via physical contact. Moreover, even human intentionality would come to be understood as reducible to material efficient causes, at least in principle.

According to the new mechanistic science, phenomena could be described with reference to a single level of the material universe known as micro-corpuscles.[32] These tiny bodies were thought to act on one another to transmit a mechanical quantity of motion via physical contact. This meant that natural processes were now understood as the transmission of force rather than, as with Aristotle and his medieval commentators, the communication of form. The macroscopic world that we experience was understood as merely an assemblage of micro-corpuscles. Just as one could explain the working of a machine by reducing it to the interactions of its moving parts, so one could explain the working of an organism by reducing it to its micro-corpuscles and their action upon each other. Within a mechanistic cosmos, there are apparently no purposes or goals as such; everything can be explained in terms of the blind mechanical actions of material elements upon one another. Those actions could be identified by the new physics through observation and mathematical explanation.

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31. See Francis Bacon, *The New Organon*, eds. Lisa Jardine and Michael Silverthorne (Cambridge: Cambridge University Press, 2000), bk. 2, aphorism 2, 102.

32. See Stephen Gaukroger, *The Collapse of Mechanism and the Rise of Sensibility: Science and the Shaping of Modernity 1680–1760* (Oxford: Oxford University Press, 2010), 58–64.

Nevertheless, a certain account of final causes or purpose remained in seventeenth and eighteenth-century physico-theology. This was largely because blind mechanism or natural necessity were thought to lead ineluctably to atheism. In 1688, Robert Boyle published his *A Disquisition about the Final Causes of Natural Things*, in which he argued that the task of the new philosophy of nature was to inquire into the purposes of things, understood as their utility for humanity. Revealing such purposes would lead to greater piety and gratitude toward God, the maker of creatures. In his Boyle lectures of 1702, published as *A Demonstration of the Being and Attributes of God*, Samuel Clarke, the principal spokesman for Newtonianism against continental Cartesianism and Spinozism in the early eighteenth century, defended a teleological view of nature that was extrinsic and grounded in the free and inscrutable will of God. Of matter, Clarke wrote,

> A tendency to move some one determinate way cannot be essential to any particle of matter, but must arise from some external cause because there is nothing in the pretended necessary nature of any particle to determine its motion necessarily and essentially one way rather than another. And a tendency or conatus equally to move every way at once is either an absolute contradiction, or at least could produce nothing in matter but an eternal rest of all and every one of its parts.[33]

For Clarke, there was nothing akin to form or intrinsic teleological order in matter. Those things that we often attribute to the natural powers of matter or the laws of motion are simply the effects of God acting on matter immediately, or mediately via created intelligences. Because the metaphysics of causation had been flattened and the traditional distinction between primary and secondary causes abandoned under the weight of a univocal doctrine of God, divine causes and created causes were now in competition. The premodern view was that God, in being the primary cause and ultimate end of all things, was the very basis of there being real and intelligible causes in nature.[34] As the ulti-

33. Samuel Clarke, *A Demonstration of the Being and Attributes of God and Other Writings*, ed. Ezio Vailati (Cambridge: Cambridge University Press, 1998), sec. 3, 19.

34. See Simon Oliver, *Creation: A Guide for the Perplexed* (London: Blooms-

mate final cause, God was understood as "the cause of the causality in all the causes."[35] By the sixteenth century, divine causation was conceived as univocal with creaturely causation in such a way that God and creatures were thought to act on the same causal plane. In order to preserve the omnipotence and freedom of God, matter was understood to be merely passive. "Nature" was evacuated of all content except the quality of being acted upon by God. Clarke writes,

> Consequently, there is no such thing as what men commonly call "the course of nature" or "the power of nature." The course of nature, truly and properly speaking, is nothing else but the will of God producing certain effects in a continued, regular, constant, and uniform manner; which course or manner of acting, being in every moment perfectly arbitrary, is as easy to be altered at any time as to be preserved.[36]

The consequence of this understanding of matter, final causes and nature, and the impoverished metaphysics that surrounded it, were deeply significant in the development of Western science. The historian of science Jessica Riskin has recently pointed to one striking effect of the banishment of agency from nature. She is particularly concerned with the rhetoric of contemporary biology under the continued influence of early modern physics. On the one hand, biology deals with life and therefore agency. Biologists find it very difficult, if not impossible, to banish the concept of purpose from their discourse. It is hard to give an account of the immune system, for example, without pointing to the goal of health. On the other hand, biology is under pressure from the allegedly more fundamental sciences of physics and chemistry to banish agency from nature and account for life in terms of interactions between the material components of a mechanism. So Riskin writes,

> I think that biologists' figures of speech reflect a deeply hidden yet abiding quandary created by the seventeenth-

bury, 2017), 75–80.

35. See note 21 above.

36. Clarke, "From a Discourse Concerning the Unchangeable Obligations of Natural Religion," in *A Demonstration of the Being*, 149.

> century banishment of agency from nature: do the order and action in the natural world originate inside or outside? Either answer raises big problems. Saying "inside" violates the ban on ascriptions of agency to natural phenomena such as cells or molecules, and so risks sounding mystical and magical. Saying "outside" assumes a supernatural source of nature's order, and so violates another scientific principle, the principle of naturalism.[37]

Riskin points precisely to the problem of intrinsic and extrinsic teleology considered earlier in this article. If the order and teleology of nature is intrinsic, we have to say that entities such as molecules and organisms are not simply mechanisms; they are agents whose agency emerges from within and expresses what they are. To account for such agency, we would need an account of causation that is far more comprehensive than simple mechanistic efficient causes. On the other hand, if the order and teleology of nature is extrinsic to nature, it must be ascribed to a supernatural agent such as God. Then we return to a divine designer, an idea that is roundly rejected by contemporary science as inimical to a discipline that must refer only to natural causes.

A further consequence of the demise of formal and final causation was the fragmentation of natural philosophy itself, particularly the area of inquiry that is broadly associated with physics. The mechanistic theory that accompanied the corpuscular theory of matter was questioned early in the eighteenth century because some phenomena, particularly gravity and action at a distance, did not easily submit to this mode of explanation. In the work of figures such as Leibniz, an attempt was made to enrich the corpuscular theory of matter with a new metaphysics in order to give a more complete explanation of natural phenomena.[38] Meanwhile, as Stephen Gaukroger points out, disciplines that examined the physical features of things (those concerned with matter theory) such as electricity, chemistry, physiology, and pneumatics, had no necessary or substantial connection with one

37. Jessica Riskin, *The Restless Clock: A History of the Centuries-Long Argument over What Makes Living Things Tick* (Chicago: The University of Chicago Press, 2016), 6.

38. Gaukroger, *The Collapse of Mechanism*, 330–31.

another.[39] There was no unifying conception of matter nor an overarching metaphysical framework within which nature might be conceived as whole and intelligible. In particular, Gaukroger points to the difficulties exemplified in Newton's *Opticks* of 1704, which indicate the problems raised by the behavior of matter: Is it particulate or fluid? Most pressingly, was gravity due to a corpuscular or a fluid ether?[40] Newton himself maintained a strict corpuscular theory of matter in the famous "31st Query" in the 4th edition of the *Opticks* (1730), but the ability of that theory to account for the full range of natural phenomena, including the behavior of light, was widely called into question.[41]

As Riskin and Gaukroger demonstrate, the corpuscular theory of matter and the mechanistic understanding of nature established a new but problematic understanding of the priority of natural philosophy. For Aristotle, living things, particularly the unity and wholeness of the organism, were understood as the principal focus of natural philosophical inquiry in relation to which all matter had to be understood. Generation and corruption of life were paradigms of change, and the overarching metaphysical framework for this inquiry was formal and final causation. By the eighteenth century, this priority had been reversed in such a way that living things had to be understood in terms of biomechanics and the physics of nonliving corpuscular matter. As mechanism came under critical scrutiny in the eighteenth century, its ability to account for life was regarded as deeply compromised. Matter was now understood as fluid living matter *or* dry dead matter.[42] What had been lost to early modern

39. Ibid., 329.

40. Ibid., 331.

41. Isaac Newton, *Opticks* (New York: Dover Publications, 1979), bk. 3.1, query 31, 389: "All Bodies seem to be composed of hard Particles: For otherwise Fluids would not congeal; as Water, Oils, Vinegar, and Spirit or Oil of Vitriol do by freezing. . . . Even the Rays of Light seem to be hard Bodies; for otherwise they would not retain different Properties in their different Sides. And therefore Hardness may be reckon'd the Property of all uncompounded Matter. At least, this seems as evident as the universal Impenetrability of Matter."

42. Gaukroger, *The Collapse of Mechanism*, 332: "On this conception, what the mechanists had in effect concerned themselves with was dead matter, but, it was now argued, dead matter, far from being the paradigm form of matter,

physics was any sense of the intrinsic dynamism of matter that could help to explain the more critical aspects of nature such as life, or, indeed, to give an intelligible understanding of nature as anything more than an assemblage of bits of matter lacking intrinsic significance and value. The simple intuition of the critics of reductive, corpuscular physics was that parts were to be understood in terms of wholes and not vice versa, which is another way of saying that act has priority over potency. This is paradigmatically the case with the unity of the living organism to which physics seems explanatorily inadequate.

The nature and task of physics has since developed dramatically, particularly through the twentieth century. The corpuscular materialism has long given way to a different conception of energy and matter that is fundamentally dynamic. We now turn to examine twentieth-century physics and the turn from mechanism to a new conception of the wholeness of nature that hints at the possibility of a return of formal and final causation.

CONTEMPORARY PHYSICS AND THE WHOLENESS OF NATURE

A central feature of the mechanistic cosmology of early modern physics is the external relation of corpuscular matter. The material elements of the universe are understood not only as separate in space; their fundamental natures are also independent. Their interaction is only via the transmission of force. They are understood to relate externally to one another through structural arrangement, but there is no organic growth into a whole that is more than the assemblage of parts. Any teleological structure could therefore only be extrinsic, akin to that of a machine whose parts are not intrinsically or "naturally" ordered to one another. By contrast, in the growth of an organism, which in Aristotelian terms acquires a new formal unity, changes in one part can profoundly affect the other parts because they are internally or intrinsically related. The advent of relativity and quantum physics overturned the extrinsic and mechanical relation of material

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was simply matter that had lost the interesting dynamic properties of living matter and—it was argued by some—it was this latter that was the proper subject of matter theory and natural philosophy more generally."

elements and gave an account of the intrinsic relation of material substances, for example in the phenomenon known as "entanglement." In turn, this has given rise to different articulations of the wholeness of nature, for example in the work of David Bohm and Bernard d'Espagnat.[43] Bohm's notion of the implicate order of nature will be our principal focus.

Bohm identifies key areas in which quantum theory challenges mechanistic physics at a more profound level than general relativity.[44] First, movement is discontinuous because it is parcelled into discrete and indivisible quanta. This means that an electron, for example, can go from one state or position to another without passing through any intermediate states or positions. The implication of this cosmology is that every part of the universe, whether it be particle or wave, is connected to every other part at the indivisible quantum level. Second, all matter and energy have a dual nature as both wave and particle, depending on the environmental conditions such as the observing apparatus. This suggests that matter and energy have an intrinsic or organic relation to the surrounding conditions—the whole, as it were—of which they are a part. Third, there is a nonlocal connection between particles or other elements such as fields. This is an important aspect of quantum theory that features heavily in Bohm's understanding of the implicate order of nature; it has its origins in a paper by Einstein, Boris Podolsky and Nathan Rosen, which resulted in what became known as the EPR effect.[45] Imagine two particles, A and B, are located together and have spin such that their total spin is zero. Spin is a vector quantity having magnitude and direction. According to quantum me-

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43. Bernard d'Espagnat, *On Physics and Philosophy* (Princeton: Princeton University Press, 2006); and David Bohm, *Wholeness and the Implicate Order* (London: Routledge Classics, 2002). D'Espagnat's neo-Kantian approach, which postulates a "veiled reality" lying behind the scientific encounter with nature, has proved influential but very controversial among philosophers of science. See d'Espagnat, *On Physics and Philosophy*, esp. 236–45.

44. Bohm, *Wholeness and the Implicate Order*, 222. For an excellent summary, see Bohm, "The Implicate Order: A New Approach to the Nature of Reality," in *Beyond Mechanism: The Universe in Physics and Recent Catholic Thought*, ed. David L. Schindler (Lanham, MD: University Press of America, 1986), 13–37.

45. Albert Einstein et al., "Can Quantum-Mechanical Description of Physical Reality Be Considered Complete?" *Physical Review* 47 (1935): 777–80.

chanics, one cannot determine all aspects of the spin of particle A without that measurement affecting particle B, even if they are moving apart at the speed of light and therefore not locally connected. The two particles are "entangled" in the sense that, having been locally associated but now separate, what happens to particle A affects particle B. This thought experiment remained empirically unverified until a paper by John Bell in the 1960s showed the nonlocal nature of quantum mechanics (the famous "Bell Inequalities"), which, in turn, led to experiments in the 1980s undertaken by Alan Aspect that confirmed Bell's theorem.[46] Quantum entities remain mutually entangled, regardless of the spatial distance between them.

The interpretation of phenomena such as entanglement and nonlocal causality is still a matter of considerable debate. According to Bohm, this aspect of quantum physics implies an implicate order to the universe that binds every part into a whole. He uses two striking examples to describe that order and distinguish it from the order conceived in a mechanistic cosmology.[47] The first, the lens, was central to the development of modern science in instruments such as the telescope and microscope. Imagine an object that forms an image through a lens, for example a camera that projects an image onto film. A given point on the object corresponds exactly to a given point on the image. This implies a correspondence between object and image, but also the divisible nature of both into component parts that are extrinsically related. The lens, which is able to deliver images of things too small, too far away, too fast, or too slow to see with the naked eye, supports the idea that our knowledge is similarly a mechanical representation of reality that is merely the composition of parts.[48] Our knowledge of nature becomes simply the assemblage of our knowledge of the bits of nature. In addition to

46. John Bell, "On the Einstein-Podolsky-Rosen Paradox," *Physics* 1, no. 3 (1964): 195–200.

47. Bohm, *Wholeness and the Implicate Order*, 182–97.

48. The history of knowledge as representation, implying that our knowledge is not of the world but of an image of the world, extends at least as far back as John Duns Scotus. See Olivier Boulnois, *Être et représentation: Une généalogie de la métaphysique moderne à l'époque de Duns Scot (XIIIe–XIVe siècle)* (Paris: Presses Universitaires de France, 1999).

the lens, Bohm offers a second means of thinking about natural order: the hologram. A hologram is a recording of a light field created by the interference pattern of a split laser beam. A laser is split, and one beam illuminates an object that is reflected onto a photographic plate, while the other beam is aimed directly at the plate. The recorded image created on the plate appears three dimensional. Two aspects of the holographic image particularly interest Bohm. First, there is not a direct one-to-one correspondence between a point on the illuminated object and a point on the image. The image is therefore not an identical "mechanical" repetition of the object. Second, and most importantly, if the holographic film is cut into pieces, each piece will have an image of the whole object. It is as if the whole object is enfolded into every part of the image. There is an indivisible implicate order. This leads Bohm to suggest that the universe is akin to a giant hologram that is subject to what he calls holomovement. The whole universe is somehow enfolded into, or implicated in, every part. Bohm writes,

> There is the germ of a new notion of order here. This order is not to be understood solely in terms of a regular arrangement of objects (e.g., in rows) or as a regular arrangement of events (e.g., in a series). Rather, a total order is contained, in some implicit sense, in each region of space and time. Now, the word "implicit" is based on the verb "to implicate." This means "to fold inward." . . . So we may be led to explore the notion that in some sense each region contains a total structure "enfolded" within it.[49]

The notion that the whole of nature is enfolded in every part of nature points away from mechanism toward an organic understanding of nature as a whole from which parts are derived. This leads Bohm to a different understanding of natural science that is more akin to Aristotelian natural philosophy than early modern physico-theology.

> In the prevailing mechanistic approach . . . these elements [e.g., fields and particles] are taken as constituting the basic reality. The task of science is then to start from such parts and

49. Bohm, *Wholeness and the Implicate Order*, 188.

> to derive all wholes through abstraction, explaining them as the results of interactions of the parts. On the contrary, when one works in terms of the implicate order, one begins with the undivided wholeness of the universe, and the task of science is to derive the parts through abstraction from the whole, explaining them as approximately separable, stable and recurrent, but externally related elements making up the relatively autonomous sub-totalities, which are to be described in terms of an explicate order.[50]

Bohm describes an order of understanding that is much more akin to the Aristotelian method focused on the priority of form and wholes: science is a matter of deriving the particular from the general rather than vice versa. The whole constitutes the fundamental reality. This is not only the case with the universe conceived as a whole through its implicate order; it is also the case with any creature whose unity constitutes its parts that are intrinsically related to one another in the sense that a change to one affects the others.

CONCLUSION

The Aristotelian-Thomistic conception of nature and natural philosophical inquiry with which we began conceived of formal and final causes as the metaphysical basis on which nature is intelligible. This treated nature as an organism in the sense that parts are intrinsically related to one another through form—the "what it is to be" something. At the same time, the form is the final cause that structures agency in nature. The teleological order is neither exclusively intrinsic nor extrinsic. It is in this overarching context—the priority of act over potency in the order of being and explanation—that matter as a potentiality is understood. Final causes are only intelligible, however, against the horizon of an ultimate finality that is desirable in itself and for no other goal. This can be conceived as the ultimate good which is convertible with being itself, namely God. Nature as a whole is understood in relation to that which is supremely One.

The advent of early modern physics in the sixteenth and seventeenth centuries saw a very different conception of mat-

50. Ibid., 226–27.

ter and nature. Mechanistic cosmology did not abandon final causes altogether, but construed teleology in entirely extrinsic terms as derived from the inscrutable will of God. Likewise, the relation of matter was extrinsic; wholes, including the whole of nature itself, were construed on the basis of fundamental particles known as corpuscles. This made a reductive physics a priority. Nevertheless, this mechanistic ontology came at a price: first, the unintelligibility of life and its inevitable reduction to dead matter that could not account for agency; second, the increasingly problematic status of matter, which was nevertheless accompanied by the conviction that matter either exhausts reality or stands incomprehensively over and against an alternate reality known as mind or spirit.

Despite the stubborn persistence of materialism as a metaphysical thesis and the widespread assumption of mechanistic cosmology in the common imagination, the twentieth-century revolution in physics has turned from mechanism toward a more organic and dynamic understanding of matter and nature. Nevertheless, the interpretation of quantum mechanics and quantum theory remains highly contested. The conception of matter in contemporary physics, which emphasizes gravitational and electromagnetic fields as well as an array of subatomic particles, remains ambiguous. Nevertheless, the findings of quantum physics suggest a renewed sense of the wholeness of nature as the very basis of natural scientific inquiry.

The implicate order described by David Bohm as an interpretation of quantum phenomena, particularly entanglement, strongly suggests the wholeness of nature and the renewal of an organic conception of the *uni*verse.[51] At the same time, the understanding of the relation of parts to the whole in the implicate order pertains to creatures and is reminiscent of Aristotelian

51. The renewed interest in the unities that ground our understanding of particulars, especially matter, is notable in the philosophy of emergence and powers metaphysics. This is particularly the case in the philosophy of mind. While there is much promise in these fields, the extent to which the understanding of the emergent properties of matter remains committed to an underlying materialism and nominalism suggests clear differences to the Aristotelian and Thomistic view of form and finality. For an excellent critical discussion within an Aristotelian-Thomistic framework, see Mariusz Tabaczek, *Emergence: Towards a New Metaphysics and Philosophy of Science* (Notre Dame: University of Notre Dame Press, 2019).

forms: in both formula and substance, the whole is prior to the parts. In turn, this implies an intrinsic teleology—an orientation toward the good or actualization of the whole—grounded in the forms of creatures as a dynamic substantial unity. Bohm also describes an explicate order, and it is here that he identifies the subject matter of physics. While physics and the natural sciences begin with the implicate wholeness of nature—this being the very ground of the possibility for any intelligible science at all—they work by abstraction of particulars within that implicate order. Those particulars, which are understood as related to each other via an explicate or extrinsic order, are abstracted from the unity of nature itself. This means that physics rightly deals with abstractions and is therefore, in itself, incomplete.[52] It must be grounded in the generality of metaphysics, which treats the unity of being qua being. This is the context in which matter must be understood: not as a potentiality grounding the rest of nature (despite the statistical and probabilistic nature of the quantum domain), but a potentiality that is always grounded in the prior actuality of nature's metaphysical unity that is both formal and final. Nevertheless, as was seen above with respect to Aristotle and Aquinas, that unity is only finally intelligible in participative relation to that which is One in itself and therefore the final end of all things. □

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